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MORPHOLOGY VS. TAXONOMY IN THE FAMILY PANDANACEAE: A CASE STUDY IN THE JAVANESE SPECIES

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ABSTRACT

RAHAYU, S. E., CHIKMAWATI, T., KARTAWINATA, K. & HARTANA, A. 2012. Morphology vs. taxonomy in the family *Pandanaceae*: a case study in the Javanese species. *Reinwardtia* 13(4): 317–330. — Since a large number of characters are now known for *Freycinetia* Gaudich. and *Pandanus* Parkinson species, it appears useful to consider their use in identifying plants from Java. Fieldwork carried out for this study has provided stronger foundation for understanding morphological variation within the species. This study was undertaken to have a better understanding on the morphology of the family in order to make a better species delimitation. Characters of habit, stem, leaves, auricles, bracts, peduncle and pedicel, inflorescence, staminate flowers (male), pistillate flowers (female), cephalia and berries were found useful in delimitation and identification of Javanese *Freycinetia*, while characters of habit, stem, prop root, marginal spine, leaves, bracts, inflorescentia, peduncle, staminate flowers (male), pistillate flowers (female), cephalia, drupes were found to be useful for distinguishing among species of Javanese *Pandanus*.

Key words: *Freycinetia*, morphology, *Pandanus*, taxonomy, Java.

ABSTRAK

RAHAYU, S. E., CHIKMAWATI, T., KARTAWINATA, K. & HARTANA, A. 2012. Morfologi vs. taksonomi pada suku *Pandanaceae*: studi kasus jenis dari Jawa. *Reinwardtia* 13(4): 317–330. — Saat ini telah diketahui adanya sejumlah karakter yang dimiliki oleh *Freycinetia* Gaudich. dan *Pandanus* Parkinson, karena itu akan sangat berguna untuk mempertimbangkan manfaat karakter-karakter tersebut untuk identifikasi tumbuhan yang berasal dari Jawa. Studi lapangan yang dilakukan pada penelitian ini memberikan dasar yang lebih kuat untuk dapat memahami variasi morfologi yang terdapat di dalam jenis. Tujuan dari penelitian ini adalah untuk memahami dengan lebih baik tentang morfologi di dalam suku sehingga dapat membuat batasan jenis yang lebih baik. Karakter-karakter seperti perawakan, batang, daun, aurikel, braktea, gagang dan gantilan bunga, perbungaan, bunga jantan dan bunga betina, sefalia dan buah berguna di dalam pembatasan dan identifikasi *Freycinetia* yang berasal dari Jawa, sedangkan karakter-karakter seperti perawakan, batang, akar tunjang, duri pinggir daun, daun, braktea, perbungaan, gagang bunga, bunga jantan, bunga betina dan buah terbukti berguna untuk pengenalan jenis-jenis *Pandanus* di Jawa.

Kata Kunci: *Freycinetia*, morfologi, *Pandanus*, taksonomi, Jawa.

INTRODUCTION

The last attempt at a comprehensive treatment of *Pandanaceae* of Java was Backer and Bakhuizen van den Brink (1968) in their “Flora of Java” in which they recognized seven species of *Freycinetia* Gaudich. and fifteen species of *Pandanus* Parkinson. Since a short visit to Hortus Bogorienses

by Stone (1972), no further exploration of the pandan flora of the island has been made, thus the pandan flora remains largely unknown.

Since a large number of characters are now known for *Freycinetia* and *Pandanus* species, it appears useful to consider their use in identifying plants from Java and to distangle the taxonomy of these species on the Island. The species are

invariably classified by the feature of the staminate plant for several reasons (Kam, 1971; Stone, 1983). As flowering is seasonal in most pandans, while fruit development is a lengthy process, there is much higher probability of finding pistillate trees with partly developed fruits, than there is of finding staminate flowers at anthesis, because the staminate flowers are very short-lived. Generally they bloom and decay within 2 or 3 days. The fruit offers a greater number of useful diagnostic features. Fieldwork carried out for this study has provided a stronger foundation for understanding morphological variation within the genus.

Characters of leaf shape, leaf apex, morphology of leaf auricles and type of pistillate inflorescence were found useful in delimitation and identification of Javanese *Freycinetia*, while characters of habit, surface of stem, presence or absence of prop root, surface of prop root, leaf shape, leaf apex, armature of leaf margins and midrib, colour of leaf margin and midrib teeth, distinctness or indistinctness of tertiary cross vein, present or absent of apical ventral pleats, phalange shapes, position of infructescence, position of seed chamber and stigma shape are proved useful for distinguishing among species of Javanese *Pandanus*.

This study was undertaken to have a better understanding of the morphology of the family in order to make a better species delimitation, particularly for species found in Java.

MATERIALS AND METHODS

A morphological study of Javanese species of *Pandanaceae* was conducted. This study was based

mainly on available herbarium specimens at the BO, K and L and specimens obtained from field work in different location in Java. In addition, five species grown in Bogor Botanical Garden viz. *Pandanus kurzii* Merr., *P. labyrinthicus* Kurz ex Miq., *P. multifurcatus* Fagerl., *P. polycephalus* Lam. and *P. spinistigmaticus* Fagerl. were also studied. The process of undertaking in this study followed the methods described by Rifai (1976) and Vogel (1987).

Basic morphological characters such as habit, stem, leaves, inflorescence, staminate flower, pistillate flower, fruit and their details were used to describe and recognize taxa; all morphological data was used for producing the description of each taxon, while the key to species was constructed from the diagnostic characters only.

The morphological species concept was applied as a framework to define taxa, in which distinction is based on perceived discontinuities in morphological variation (Davis & Heywood, 1963).

RESULTS

Morphology of Javanese *Freycinetia*

Habit

All species of *Freycinetia* found in Java are climber with different sizes. Three species of *Freycinetia* (*F. imbricata* Blume, *F. javanica* Blume and *F. scandens* Gaudich.) are smaller to medium climbers, while *F. insignis* Blume and *F. sumatrana* Hemsl. are medium climbers, and the smaller climber is found in *F. angustifolia* Blume.

The stems are found hanging on trees and are highly branch, e.g. *F. angustifolia* and *F. javanica*

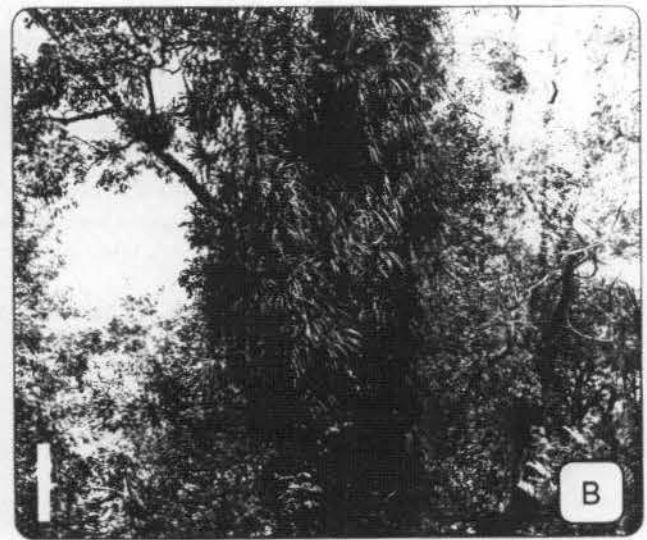
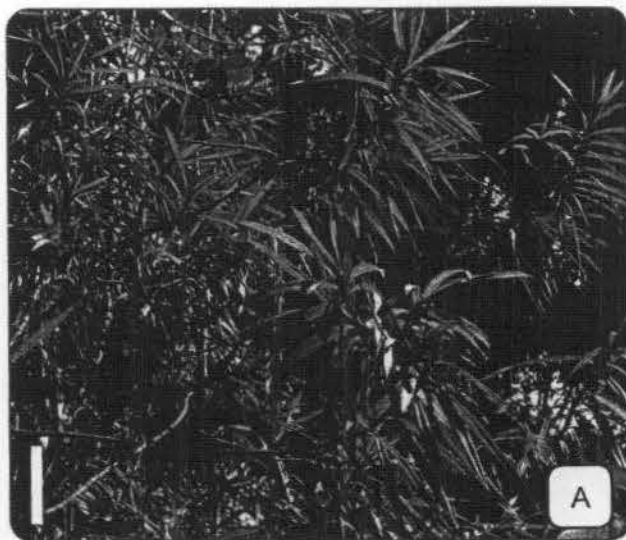


Fig. 1. Habit of *Freycinetia* spp.: A. *F. javanica*, scale bar = 15 cm. B. *F. sumatrana*, scale bar = 2 m.

(Fig. 1 A); while in *F. imbricata* the main stem remain adherent to tree trunk, and in some cases makes a complete cover which makes the trunk of the host tree invisible, e.g. *F. insignis* and *F. sumatrana* (Fig. 1 B).

Stem

Stems of Javanese *Freycinetia* vary in size, nodes and colour. In terms of size, *F. angustifolia*, *F. imbricata*, *F. javanica* and *F. scandens* are classified as slender species, while *F. funicularis*, *F. insignis* and *F. sumatrana* are classified as robust species.

Variation is observed in stem shape. This study showed that *F. angustifolia*, *F. imbricata*, *F. insignis*, *F. scandens*, and *F. sumatrana* had terete stems, whereas *F. javanica* had a subterete to terete stem.

Variation is also observed in internode shape. This study showed that *F. angustifolia*, *F. imbricata*, *F. insignis*, *F. javanica*, and *F. sumatrana* had terete internodes, whereas *F. scandens* had a subterete to terete internode. The surface of the stem can be sulcate or sulcate to canaliculate. The colour also varies from yellowish, greenish brown to reddish brown. *F. angustifolia* had yellowish green stem, *F. insignis* had greyish green stem, *F. javanica* had greenish brown, reddish brown to dark reddish brown, whereas *F. scandens* had yellowish green to green stem.

Leaves

The leaves of *Freycinetia* are usually green to dark green coloured on the upper surface, but paler green on the lower surface. In Java *F. angustifolia* possesses the smallest (10.5–64 × 0.3–1.7 cm) and most slender leaves, whereas *F. sumatrana* has the most robust leaves. The leaves arrangement in species of *Freycinetia* found in Java is alternate and imbricate. Four species of *Freycinetia* (*F. angustifolia*, *F. funicularis*, *F. javanica* and *F. scandens*) have alternate leaves, and the other three species (*F. imbricata*, *F. insignis* and *F. sumatrana*) have imbricate leaves.

Leaves are simple blade and usually linear-lanceolate in outline, but variation does exist in some species. *F. scandens* has variation in leaf shape, from elliptic, oblanceolate to lanceolate. Leaf apex can be abruptly attenuate below the apex to gradually attenuate toward the subulate apex, in *F. sumatrana* it is long and tapering to a slender subulate tip, whereas the lamina of *F. javanica* is gradually attenuate toward the base. The margin usually was armed in basal part, apical part and upper midrib of its leaves with serrate prickles. The

basal part of *F. insignis* and *F. scandens* are denticulate, and basal part of *F. sumatrana* is dentate. The colour of the prickles may be wholly straw coloured or with brown tips as in *F. angustifolia*. The laminar part can be chartaceous, subcoriaceous to coriaceous.

Auricles

The auricle is an organ of flange-like extensions found on the leaf-sheath, and can be easily seen on the young leaf. Auricles are usually membranous (Fig. 2 A), coriaceous (Fig. 2 B), transparent (Fig. 2C), or fragile (2D). Auricles can be regarded as a good identification character of *Freycinetia* in the field, because in herbarium specimen they are rarely seen in good condition. The shape, size, texture, nature of margin, nerves and colour of auricle varies between species. *Freycinetia angustifolia* possess the smallest auricle, while *F. sumatrana* possess the biggest auricle. Colour of auricles also varies from pale green in *F. insignis* to brownish green – brownish yellow in *F. javanica*.

In *Freycinetia*, they vary from tapered or rounded to the apex or adnate to the apex. The margin is entire or denticulate to spinulose at apex (*F. insignis*), or armed almost to the base (*F. imbricata*). The lamina is usually membranous in *F. javanica* (Fig. 2 A) or coriaceous in *F. insignis* (Fig. 2 B), some of them fragmenting transversally in *F. sumatrana* or fragmenting transversally, in *F. scandens*, with 4 widely spaced nerved in *F. insignis* or 1–2 septate in *F. javanica*.

Bracts

Bracts are persistence or caducous, located on the peduncle. Bracts vary in shapes and sizes. Bracts are usually ovate, cymbiform to lanceolate, with entire margin to slightly armed with prickles. The sizes of bracts are concurrent with their habits. Slender species like *F. angustifolia*, *F. imbricata* and *F. javanica* possess minute bracts, while robust species such as *F. insignis* and *F. sumatrana* also have robust bracts. Their apexes have various shapes, varying according to the species from acute to acuminate in *F. imbricata*, acute to cuspidate in *F. javanica*, mucronate to aristate in *F. angustifolia*, and aristate with aculeate prickles in *F. sumatrana*.

Peduncle and pedicel

The peduncle usually is straight and short. The peduncle may be slender or robust, densely or sparsely pubescent or rarely glabrous, only in *F. insignis* does the peduncle have a bract scar. Usually the pedicel is longer than the peduncle. The

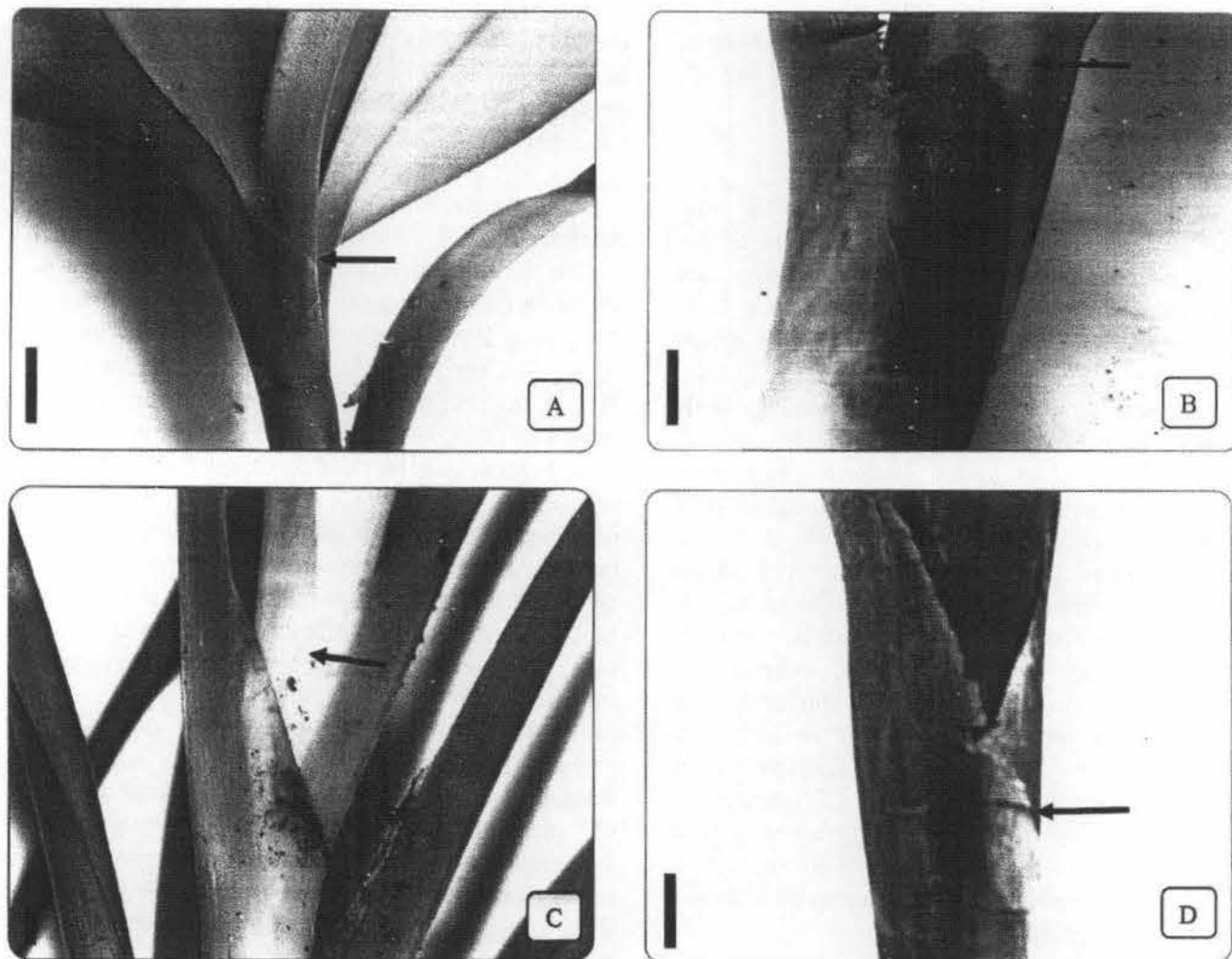


Fig. 2. Auricles type of *Freycinetia* spp.: A. Membranous (*F. javanica*). B. Coriaceous (*F. insignis*). C. Transparent (*F. angustifolia*). D. Fragmenting transversally (*F. sumatrana*). Auricles was shown with arrow. Scale bar = 2 cm.

pedicel shape usually is subterete, slender (*F. scandens*), usually as thick as peduncle, or only somewhat stouter than the peduncle with 0.2–1.5 cm in diameter (*F. insignis*). The surface of pedicels can be glabrous or covered with indumentum. *F. angustifolia*, *F. javanica* and *F. scandens* had glabrous pedicel, while *F. imbricata* and *F. insignis* had puberulous to hirsute pedicel.

Inflorescence

The inflorescence in most of *Freycinetia* found in Java are usually located on terminal part of the stems (*i.e.* terminal inflorescence). Lateral inflorescence are less often seen. This study showed that there is one species that possesses such a feature, *viz.* *F. funicularis*. In lateral inflorescences, not only a bract is present, but also prophyll, that is located in the upper part of bracts.

Freycinetia is mostly dioecious, which means that male and female flowers are formed on

different plants. Staminate inflorescences are invariably terminal on a normal leafy shoot, usually a raceme of spikes, each of the three or four spikes. The staminate material is poorly represented in herbaria and in collection, in this study we only found two staminate inflorescence of *F. angustifolia* and *F. javanica*. Both species had the same type of staminate inflorescence, *i.e.* a raceme of three or four spikes.

Staminate inflorescences are more rarely seen than pistillate inflorescences, because anthesis in staminate inflorescence is short (one to three days), often when it dries up (Stone, 1983). Similar to other genera of *Pandanaceae*, *Freycinetia* identification is therefore mainly based on the structure of female inflorescence and infructescence.

In *Freycinetia*, the spikes (both male and female) tend to be closely adjacent and often ternate, so that the open ripe inflorescence seems to

be an umbel like in *F. javanica* (Fig. 3 A) or pseudoumbel. In *F. angustifolia*, the inflorescence is racemiform (Fig. 3 B), whereas in *F. funicularis*, the inflorescence is lateral (Fig. 3 C).

Staminate flowers (male)

F. angustifolia and *F. javanica* had the same type of staminate flower. The stamens are simple, without branched filaments, and each terminate is in a small rather short anther or sessile stamens.

Pistillate flowers (female)

The pistil consists of multiovulate carpels with carpels separated to the base or united. Each carpel is tipped by a stigma, and the stigma is sessile. The stigmas vary in number and shape, from 2 to 5 in number, and from ovate (*F. javanica*), depressed ovate-suborbicular (*F. angustifolia*, *F. imbricata*, and *F. insignis*), pentagonal-suborbicular (*F. scandens*) or protude (*F. funicularis*) in shape. The position of the stigma varies from horizontal to sunken in position.

Cephalia

Cephalium (plural: cephalia) is the complex fruit in *Pandanaceae*. Some of the important morphological characters in *Freycinetia* are found in the cephalia. In the Javanese species of *Freycinetia*, cephalia vary in shape, size and colour. Four species (*F. Funicularis*, *F. insignis*, *F. javanica*, and *F. sumatrana*) have cylindric cephalia. *F. angustifolia* have cylindric to oblanceolate cephalia, *F. scandens* have cylindric to oblong cephalia, and *F. imbricata* have narrowly elliptic to broadly oblong cephalia. The number of cephalia per inflorescence is usually two, three or four.

Berries

Berries are the simple fleshy fruit of *Freycinetia*. In *Freycinetia* a cephalium consisted of an numerous berries. A berry contain many fused ovules, thus is a multiovulate fruit, while in *Pandanus* the simple fruit is always uniovulate. In these circumstances a cephalium can be regarded as

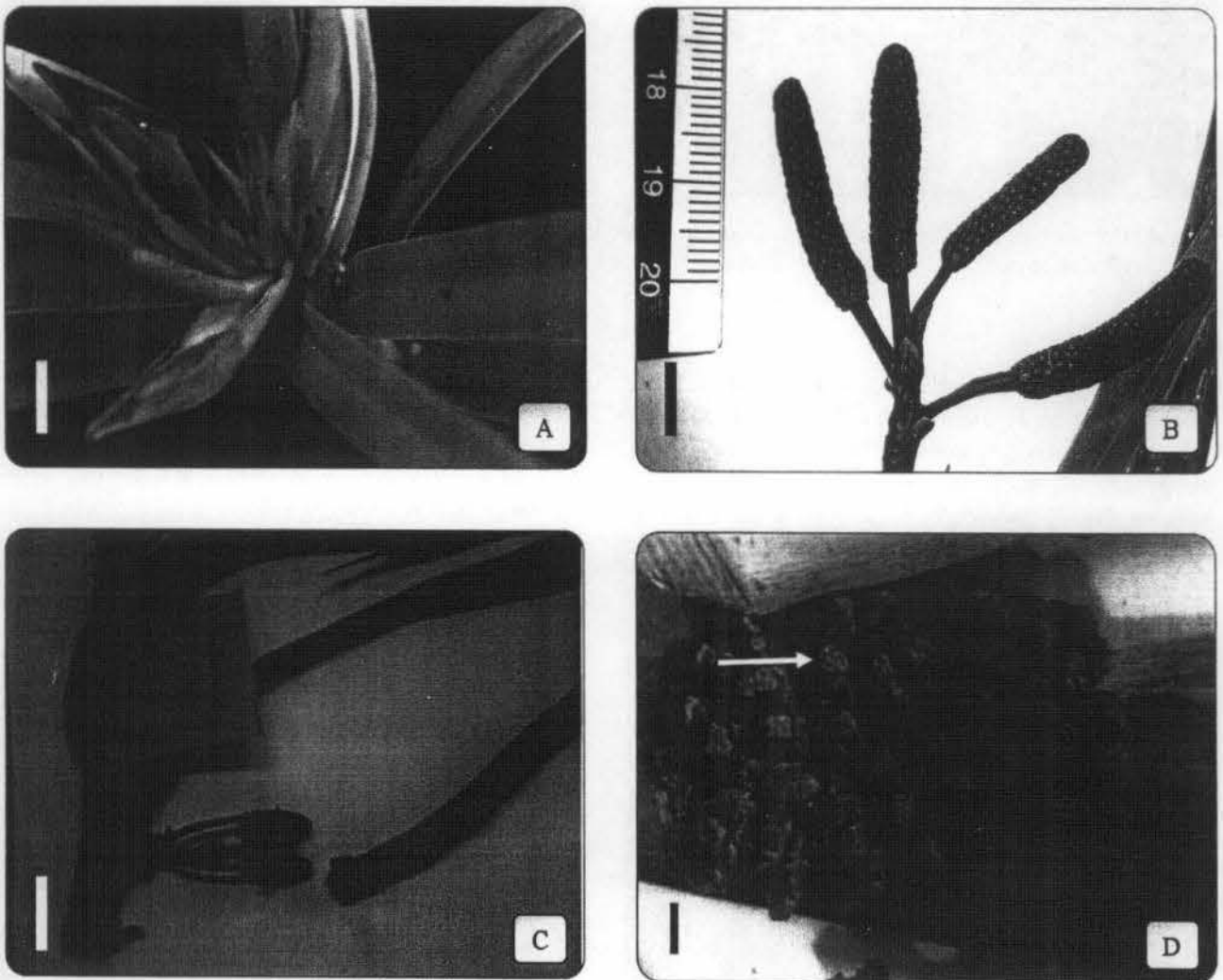


Fig. 3. Inflorescence type of *Freycinetia* spp.: A. Umbel (*F. javanica*). B. Racemiform (*F. angustifolia*). C. Lateral (*F. funicularis*). D. Remain stigma of *F. imbricata*. Scale bar for A, B and C = 1 cm; scale bar for D = 25 mm.

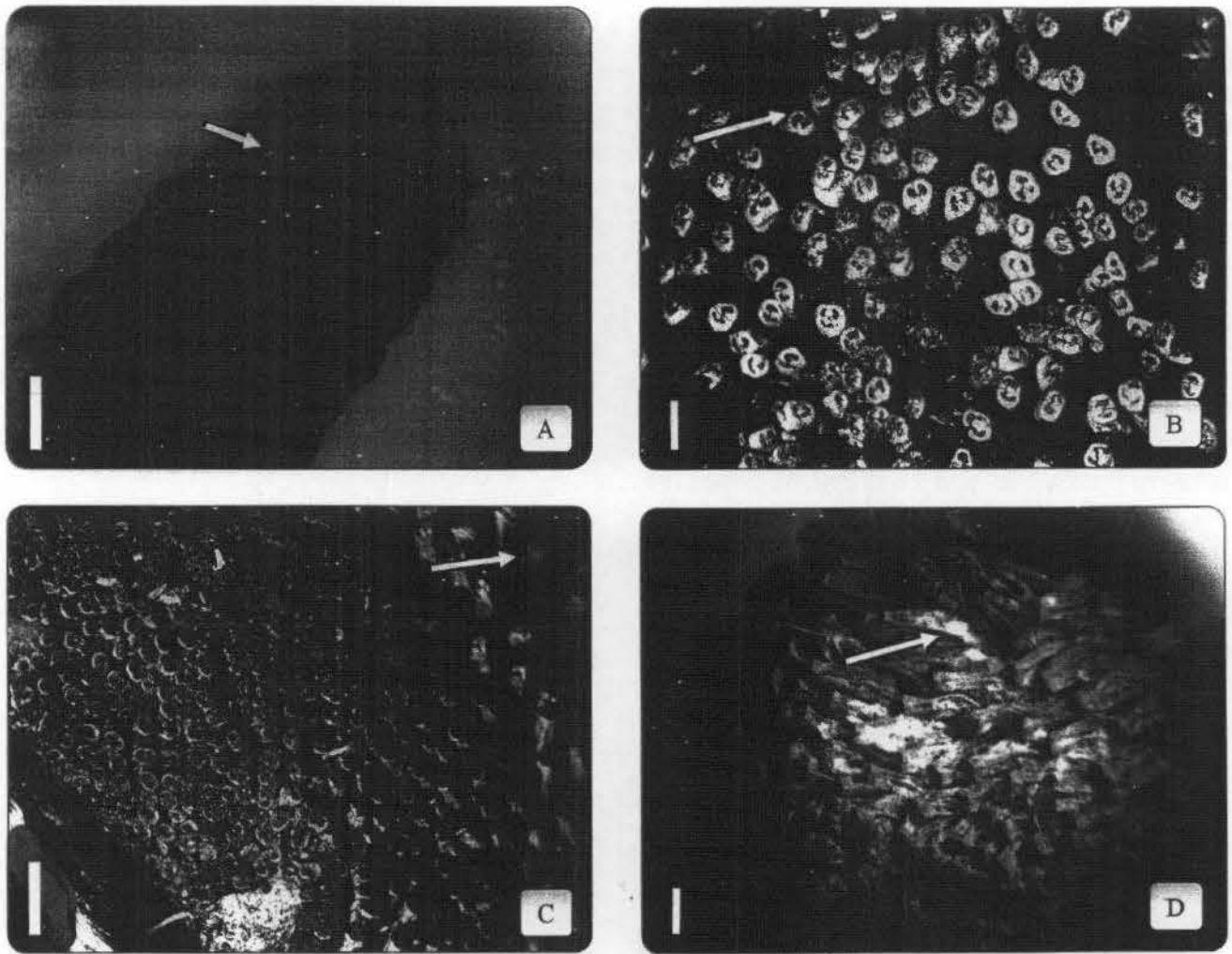


Fig. 4. Berries type of *Freycinetia* spp.: A. Obconic (*F. angustifolia*). B. Lageniform (*F. insignis*). C. Subpyramidal (*F. sumatrana*). D. Pentagonal (*F. scandens*), scale bar = 25 mm.

a complex fruit. The shape of berries varies from obconic like in *F. angustifolia* (Fig. 4 A), obovate (*F. funicularis*), oblong (*F. javanica*) and subpyramidal such as in *F. sumatrana*. Three species, viz. *F. imbricata*, *F. insignis* (Fig. 4 B) and *F. scandens* are the species observed with various

shapes of berry from pentagonal to lageniform, pentagonal, lageniform to oblong, and pentagonal, lageniform, ovate to oblong respectively. The apical part of a berry is usually harder and stiffer, while the basal part is usually fleshy.

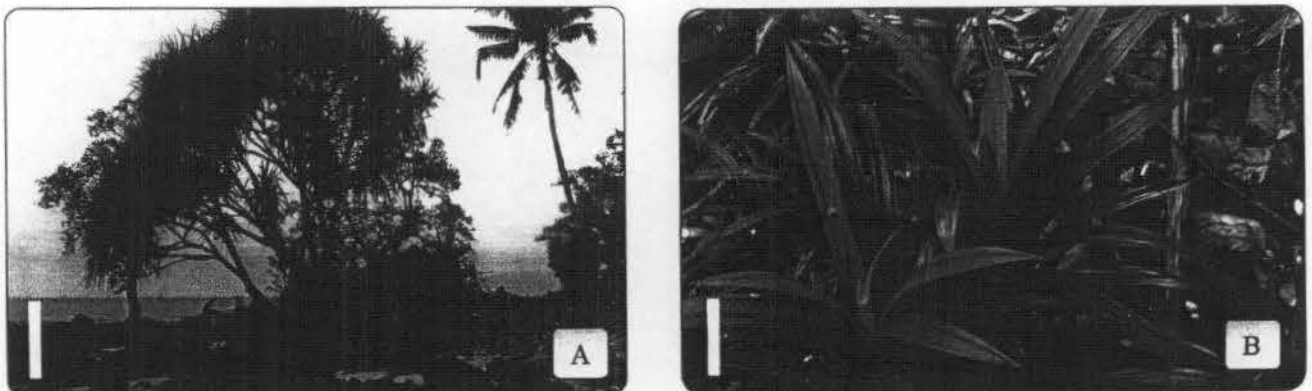


Fig. 5. Habit of *Pandanus* spp.: A. Shrub (*P. amaryllifolius*), scale bar = 10 cm. B. Tree (*P. odoratissimus*), scale bar = 1 m.

Morphology of Javanese *Pandanus*

Habit

Unlike *Freycinetia*, which has a climbing habit, the habit of *Pandanus* species found in Java varies from shrubs to trees. Shrub species are *P. amaryllifolius* Roxb. (Fig. 5 A), *P. kurzii* Merr., *P. nitidus* (Miq.) Kurz. and *P. polycephalus* Lam. Tree species include *P. bantamensis* Koord., *P. bidur* Jungh., *P. dubius* Spreng, *P. faviger* Backer, *P. labyrinthicus* Kurz. ex Miq., *P. leram* var. *andamanensium* (Kurz.) Stone, *P. multifurcatus* Fagerl., *P. odoratissimus* L.f. (Fig. 5 B), *P. pseudolais* Warb., *P. scabrifolius* Martelli ex Koord., *P. spinistigmaticus* Fagerl., *P. spurius* Miq. cv. *putat*, *P. tectorius* Parkinson and *P. utilis* Bory.

Stems

Stems of Javanese *Pandanus* vary in size, colour and branch. Slender stems are found in *P.*

amaryllifolius or short stems in *P. kurzii*. Erect stem and unbranched are found in *P. bantamensis*, *P. dubius* and *P. pseudolais*, while *P. polycephalus* has erect stem and branched. *P. labyrinthicus*, *P. multifurcatus*, *P. nitidus*, *P. odoratissimus* and *P. spinistigmaticus* has spreading branches, whereas *P. faviger*, *P. tectorius* var. *littoralis* and *P. utilis* had dichotomous branching. The surface of stem can be smooth like *P. kurzii*, sulcate in *P. amaryllifolius*, abundant rootlet to thorny in *P. bidur*, *P. dubius*, *P. labyrinthicus*, *P. multifurcatus*, *P. nitidus*, *P. odoratissimus*, *P. spinistigmaticus*, and *P. tectorius* var. *littoralis* or ringed by leaf scars in *P. polycephalus* and *P. utilis*. The colour of the stem also varies from grey to green or brownish.

Prop root

A prop root is a root formed from the stem, usually close to the ground which helps hold the



Fig. 6. Prop root type of *Pandanus* spp.: A. Slender (*P. spurius* cv. *putat*). B. Stout (*P. odoratissimus*). C. No prop root (*P. kurzii*). D. Muricate in longitudinal line (*P. utilis*). Scale bar for A = 75 cm. Scale bar for B, C and D = 5 cm.

stem erect and anchor the plant. There are variations in prop root size number and surface. Prop roots can be small and few as in *P. amaryllifolius*, small and abundant as in *P. labyrinthicus*, *P. odoratissimus* and *P. tectorius* var. *samak*, slender as in *P. spurius* cv. *putat* (Fig. 6 A), some arise from lateral branches as in *P. nitidus* and *P. spurius* cv. *putat*, long and stout as in *P. bidur*, *P. dubius*, *P. faviger*, *P. leram* var. *andamanensium*, *P. multifurcatus*, *P. odoratissimus* (Fig. 6 B) and *P. spinistigmaticus* or absent as in *P. kurzii* (Fig. 6 C). The surface of the prop root can be smooth as in *P. scabrifolius*, muricate in the longitudinal line such as in *P. utilis* (Fig. 6 D), *P. tectorius* var. *littoralis*, *P. pseudolais*, and *P. nitidus* or armed with prickles or spine in *P. spinistigmaticus*, *P. polycephalus* and *P. multifurcatus*.

Marginal Spine

Leaves usually set with prickles along its length or part of it. The prickles decrease in size nearing the leaf apex (*P. utilis*, *P. bantamensis*, *P. pseudolais*, *P. tectorius* var. *littoralis*, and *P. nitidus*), always antrorse (ascending) but those near leaf base sometimes retrorse, or absent. Their margin are usually prickly, occasionally entire (*P. spurius* cv. *putat*), or prickly very near and at apex only (*P. amaryllifolius*), or occasionally smaller at leaf base, larger at midsection and decreasing in size nearing the leaf apex (*P. bidur*, *P. dubius*, *P. odoratissimus*, and *P. scabrifolius*). Twin lateral pleats are often well distinguished, smooth (*P. bantamensis*, *P. nitidus*, *P. pseudolais*, and *P. scabrifolius*), or in some species prickly serrate or absent (*P. odoratissimus*, *P. spinistigmaticus*, *P. spurius* cv. *putat*, and *P. tectorius* var. *littoralis*).

Some species have white spines as in *P. tectorius* var. *littoralis* (Fig. 7 A), green prickles with brown tipped (*P. bantamensis*, *P. pseudolais*, and *P. scabrifolius*) or yellowish green (*P. dubius*) or red prickles in *P. utilis* (Fig. 7 B).

Leaves

The leaves of *Pandanus* are usually dark green coloured, glossy and glaucous on upper (adaxial) surface, but paler green on the lower surface, whereas in *P. tectorius* cv. *sanderi* there are longitudinal white to pale yellow bands from across the width of the leaf midrib to leaf margin. Compared with the other members of *Pandaneaceae*, the size of the leaf in *Pandanus* is noticeably longer and bigger. In Java *P. amaryllifolius* has the smallest and the most slender leaves, whereas *P. pseudolais* possesses the longest leaves (299–574.5 cm long). The leaf arrangement in all species of *Pandanus* found in Java is spiral. The leaves are simple and usually ensiform to linear in shape. However variation in leaf shape does exist in some species, such as ligulate as in *P. labyrinthicus*, *P. multifurcatus*, *P. odoratissimus* and *P. spurius* cv. *putat*. The apical part can abruptly terminate in a point to gradually long tapering to subulate apex. Caudate apices are observed only in one species, *P. dubius*. The margin can be entire as in *P. spurius* cv. *putat* or noticeably armed with spines throughout the length, except in *P. amaryllifolius* that possesses prickles only in the apical part of its leaves. The laminar part can be chartaceous, thin coriaceous, coriaceous to thick coriaceous. Longitudinal lines are more prominent abaxially, with tertiary cross veins on both surfaces. In *P. amaryllifolius*, *P. bantamensis*, *P. bidur*, *P. dubius*,

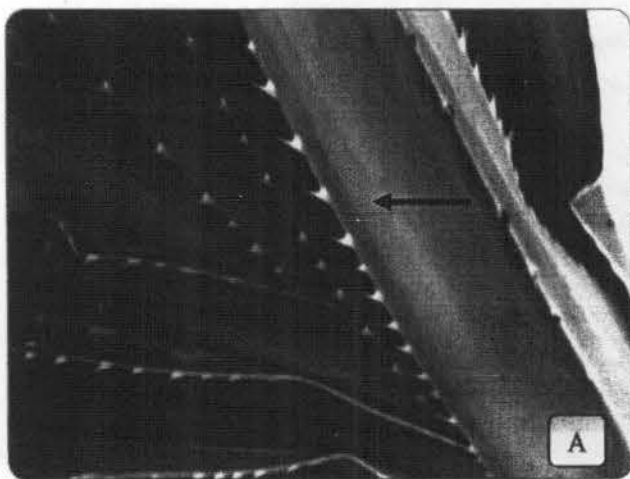


Fig. 7. Prickles type of *Pandanus* leaves: A. White prickles (*P. tectorius* var. *littoralis*). B. Red prickles (*P. utilis*). Scale bar = 1 cm.

P. kurzii, *P. pseudolais*, and *P. scabrifolius*, tertiary cross veins form a network of meshes, oblong or rhombic meshes, whereas in *P. leram* var. *andamanensium* tertiary cross vein gives a tessellate appearance. The basal part of leaves of *P. kurzii*, *P. polycephalus* and *P. scabrifolius* are whitish, reddish in *P. utilis*, or reddish brown in *P. bantamensis* and *P. pseudolais*.

Bracts

Bracts cover inflorescences and are usually formed by the three levels of trichiously arranged bracts. The interior bract covers the inflorescence, while the other two, the exterior and middle bracts, protect the interior bract and the inflorescence inside.

Bracts vary in shapes and sizes. Bracts are usually lanceolate in shape, with margins armed with prickles to spines. The sizes of bracts are concurrent with their habits. Robust species such as *P. bantamensis*, *P. pseudolais* and *P. scabrifolius* have robust bracts, while slender species like *P. nitidus* possess slender and minute bracts. The exterior bracts are leaf-like in form, except in *P. kurzii*, where the exterior bracts are cymbiform in shape. The inner bracts are shorter and lighter in colour.

The colour of bracts also varies. The colour of exterior and interior bracts can be different. The differences can be seen within the same bract. The colour of the apical part, middle and basal parts may not be uniform such as in *P. odoratissimus*, and in few species the colour of bracts are uniform such as in *P. polycephalus* (white) and *P. utilis* (green). The apex of bracts are observed abruptly acute in *P. utilis*, gradually tapering to a subulate tip in *P. labyrinthicus*, *P. odoratissimus* and *P. tectorius*.

Inflorescences

Pandanus are dioecious, which means that male and female flowers are produced on separate plants. The inflorescence in all species of *Pandanus* in Java is found on the apical part of the stem (*i.e.* terminal inflorescence). Staminate inflorescences are fragrant and usually pendent, except in *P. labyrinthicus*, where the staminate inflorescence is erect (Fig. 8 A). Staminate inflorescences also vary in size. In *P. odoratissimus*, the raceme bear 9–18 lateral racemes, the size of each spike is 21.3–33 cm long, whereas in *P. utilis*, the raceme bear 20 lateral racemes, the size of each spike is 41–43 cm long (Fig. 8 B). Staminate inflorescences are more rarely seen than that pistillate inflorescences, therefore *Pandanus* identification is mainly based on the structure of female inflorescences and infructescence.

Pistillate inflorescences may be represented by a single cephalium (head) as in *P. odoratissimus* (Fig. 8 C) or by a spike of several cephalia. In *P. faviger*, the pistillate inflorescences are observed as a spike of three cephalia, whereas in *P. polycephalus* the pistillate inflorescence is a raceme of spikes (Fig. 8 D).

Peduncle

The peduncle is generally straight, stout and glabrous, but can be as in *P. bantamensis*, *P. tectorius* var. *littoralis*, and *P. utilis*, a bit curved at the end; while in *P. pseudolais* it is curved at the end. Their shape is usually 3-sided, whereas in *P. polycephalus* it is obtusely trigonous. Their size is larger at the apex and decreases towards the base. Their colour varies according to the species from whitish green (*P. bantamensis*) to green (*P. pseudolais* and *P. utilis*).

Staminate flower (male)

The stamens are borne in small or large clusters on short or long axes (*P. labyrinthicus*, *P. odoratissimus*, *P. spurius* cv. *putat*, *P. tectorius* var. *littoralis*, and *P. utilis*). Most of the male flowers are sessile (Fig. 9 A), whereas in *P. utilis* it is filantherous (Fig. 9 B).

Pistillate flower (female)

Pistillate flowers consist of a single uniovulate carpel with a single stigma or many. The stigma may be sessile as in *P. bidur*, *P. dubius*, *P. odoratissimus*, *P. polycephalus*, *P. tectorius* var. *littoralis*, and *P. utilis* (Fig. 10 A) or borne on the style in *P. bantamensis*, *P. kurzii*, *P. nitidus*, *P. pseudolais*, and *P. scabrifolius* (Fig. 10 B). The stigmas have various shapes, varying according to the species from linear (*P. kurzii*) or rounded (*P. polycephalus*), cordate, elliptic, lanceolate, lip-like (*P. bidur*) or forked (*P. bantamensis*, and *P. scabrifolius*). The position of stigmas are adaxial.

Cephalia

Some of the important morphological characters for species identification in *Pandanus* are in their cephalia (number, shape, *etc.*). In the Javanese species of *Pandanus*, cephalia vary in shape, size and colour. Five species (*P. kurzii*, *P. odoratissimus*, *P. scabrifolius*, *P. tectorius* var. *littoralis* and *P. utilis*) have subglobose cephalia, while the other species such as in *P. bantamensis*, *P. nitidus*, *P. polycephalus* and *P. pseudolais* possess ellipsoid to oblong cephalia. The number of cephalia per infructescence is usually one, other numbers such as three, five or six are also present but less common in Java.



Fig. 8. Inflorescence type of *Pandanus* spp.: A. Staminate inflorescence erect (*P. labyrinthicus*), B. Long staminate inflorescence (*P. utilis*), C. Pistillate inflorescence in spike (*P. odoratissimus*), D. Raceme of spikes (*P. polycephalus*). Scale bar for A and B = 10 cm. Scale bar for C and D = 2 cm.

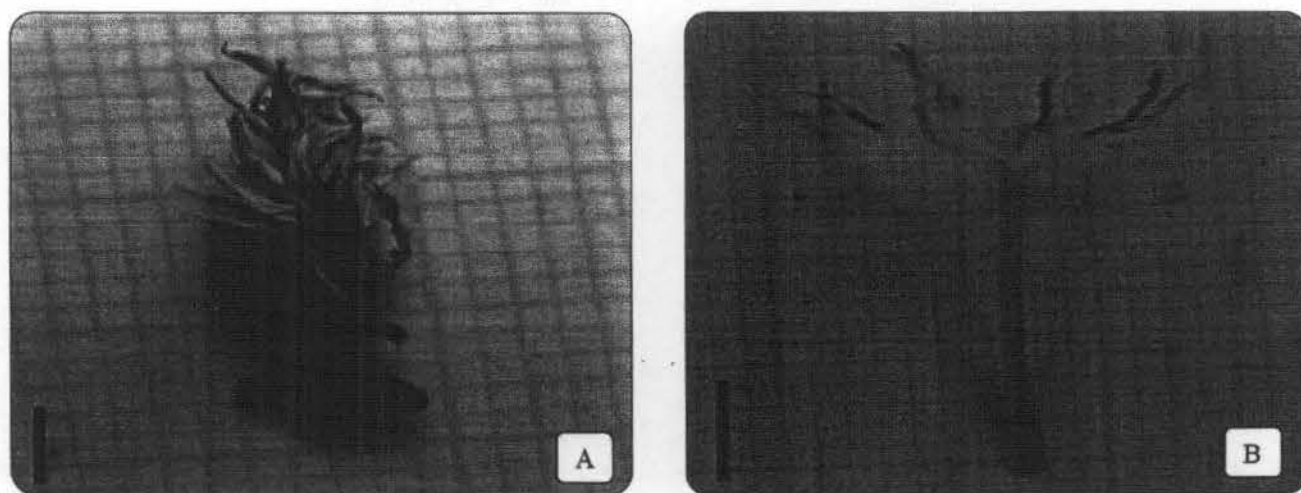


Fig. 9. Stamen types of *Pandanus* spp.: A. Sessile (*P. tectorius* var. *littoralis*), B. Filantherous (*P. utilis*), scale bar = 2 cm.

In *Pandanus*, a cephalium can consists of numerous monocarpellate drupes or numerous pluricarpellate drupes or phalanges. Monocarpellate drupes are composed of free, a single carpel while pluricarpellate drupes (polydrupes) are carpels that are permanently fused into a compound structure. Drupes are of great importance in *Pandanus* classification. The result of this study showed that seven species (*P. bantamensis* (Fig. 11 A and B), *P. faviger*, *P. kurzii*, *P. nitidus*, *P. polycephalus*, *P. pseudolais* and *P. scabrifolius*) have cephalium with numerous monocarpellate drupes, while the other species such as in *P. bidur*, *P. dubius*, *P. leram* var. *andamanensium*, *P. odoratissimus*, *P. tectorius* var. *littoralis* and *P. utilis* (Fig. 11 C and D) have cephalia with numerous pluricarpellate drupes. Monocarpellate drupe varies in shape from conical, cuneate to oblanceolate, while pluricarpellate drupes vary from clavate, cuneate, obovate to oblong.

Monocarpellate drupes usually have one stigma while pluricarpellate drupes (polydrupes) have more than one stigma. Some species have sessile stigma, while in other species the stigma is on the style. The surfaces of cephalium can be smooth, such as in *P. utilis* or covered by flat scales like in *P. kurzii* (Fig. 11 E), while the surface of the apical of pluricarpellate drupes of *Pandanus* usually have no cracks on centre apical sinuses, except in *Pandanus tectorius* var. *littoralis*, where there are cracks on the centre of apical sinuses on its the surface apical of the pluricarpellate drupe (Fig. 11F). The apical part of monocarpellate or pluricarpellate drupe is usually harder, and the basal part is usually fibrous and fleshy.

DISCUSSION

The taxonomy of the Javanese species of *Pandanaceae* is presently in a unsatisfactory state. Since Flora of Java in 1986, a number of species have been described which have never been compared. Some of their status is still more or less in question.

Morphological data are regarded as the most appropriate and the most rapid mean for identification and for constructing map of diversity of plant (Davis & Heywood, 1963), and morphological characters have the great advantage over other characters that we can see the plant variability easier.

Since a large number of characters is now known for *Freycinetia* and *Pandanus* species, it appears useful to consider their use in identifying plants from Java, and the use of a large number of characters may give more accurate identification. Moreover, the current study clearly defines the species status among the members of each genus through morphological observation of a good number of specimen of each species.

Pandanus furcatus is the most heterogenous and complex species in *Pandanus*. Backer and Bakhuizen van den Brink (1968) classified *P. bantamensis*, *P. oviger*, *P. pseudolais* and *P. scabrifolius* as one species, *P. furcatus*, because of the presence of bifid styles. Stone (1972) on the other hand, treated these plants as four different species based on cephalia characters as stated by Kam (1971) that fruit offered great number of useful diagnostic characters. In the current analysis, taxonomical status of the three of four species

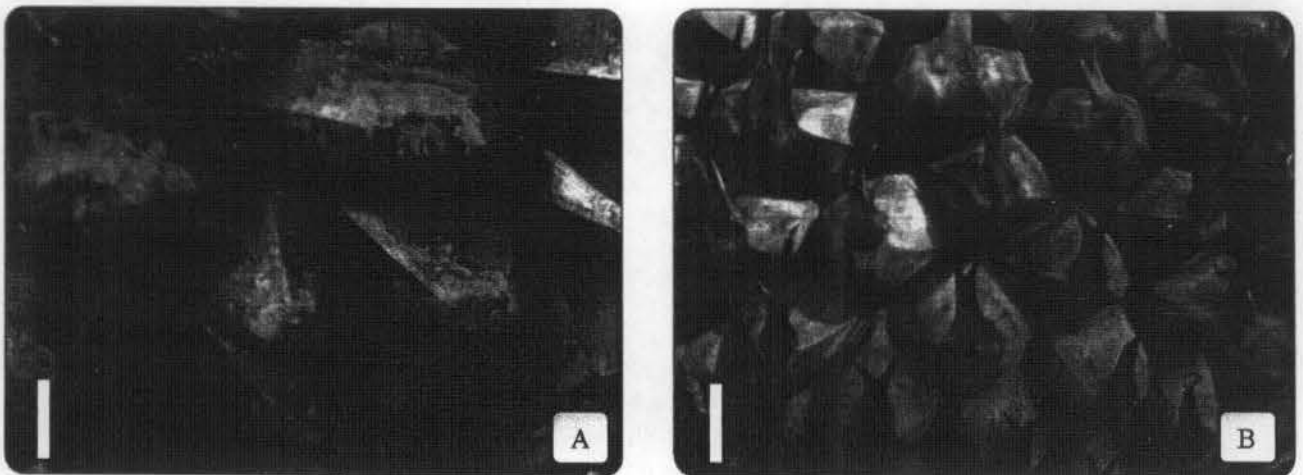


Fig. 10. Stigma type of *Pandanus* spp.: A. Sessile (*P. utilis*). B. On style (*P. scabrifolius*). Scale bar = 1 cm

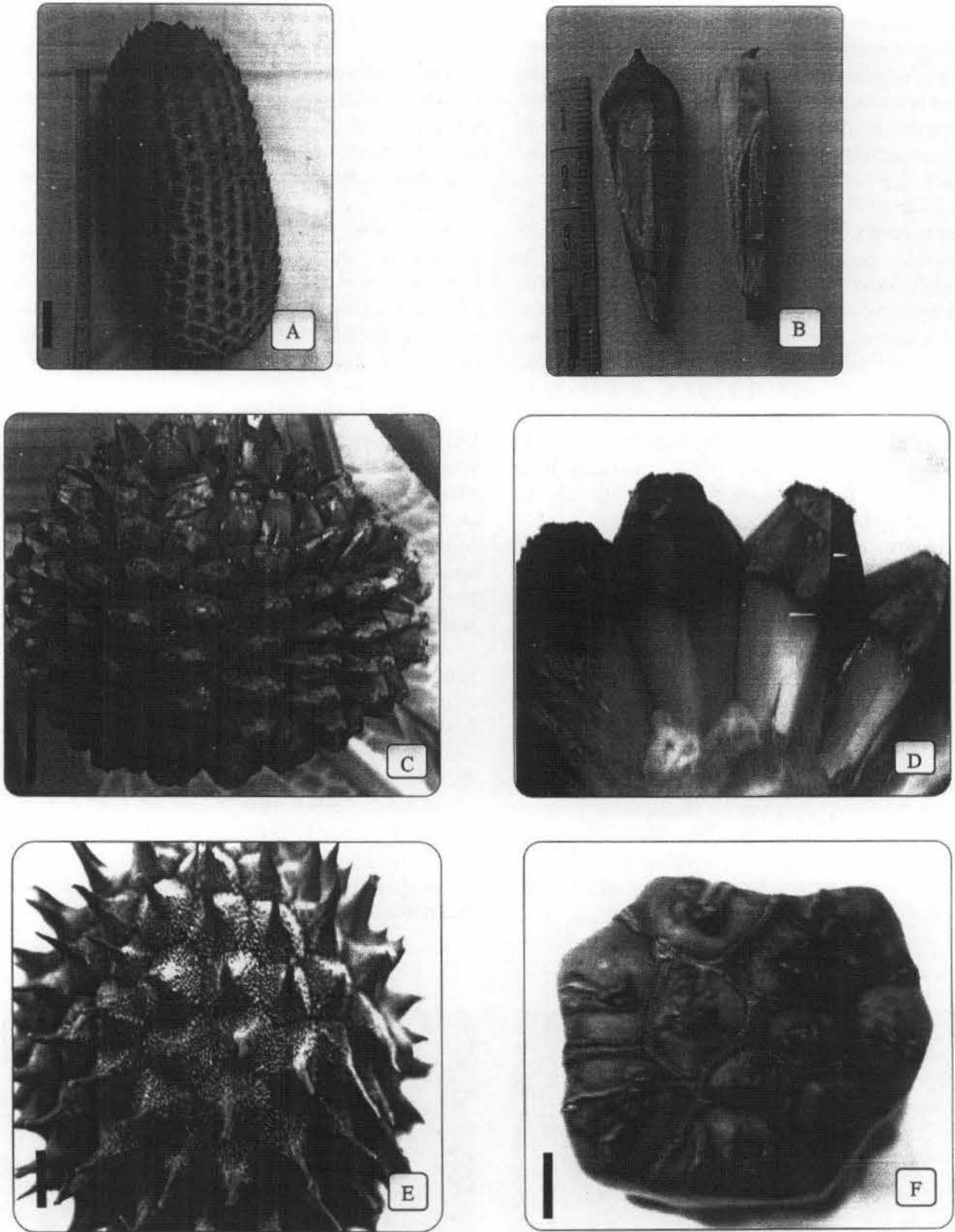


Fig. 11. Cephalaria type of *Pandanus* spp. A. Cephalaria with numerous monocarpellate drupes (*P. bantamensis*). B. Monocarpellate Drupe (*P. bantamensis*). C. Cephalaria with numerous pluricarpellate drupes (*P. utilis*). D. Pluricarpellate drupes (*P. utilis*). E. Cephalaria with numerous monocarpellate drupes covered by flat scales (*P. kurzii*). F. Pluricarpellate drupe with cracks on the centre of apical sinuses (*P. tectorius* var. *littoralis*). Scale bar for A and C = 20 cm.; scale for B, D, E and F = 1 cm.

mentioned above, viz. *P. bantamensis*, *P. pseudolais* and *P. scabrifolius*.







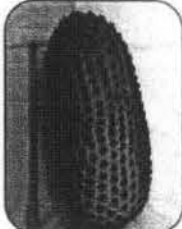





This study agrees with Stone (1972) classification and observation of *P. bantamensis*, *P. pseudolais* and *P. scabrifolius* as three different species, and not as one species of *P. furcatus* as suggested by Backer and Bakhuizen van den Brink (1968). If one compares the specimens of the tree species, they would not fail to observe the discrimination between these taxa in leaf base colour, peduncle shape, cephalia shape and style shape (Rahayu *et al.*, 2011).

The newly information (character) we found in this study for *Freycinetia*, i.e. stem shape, leaves

arrangement, and surface of pedicels, whereas for *Pandanus*, i.e. branching of stem, prop root size, prop root surface and leaf marginal spine colour.

Pandanaceae species in Java were classified by the feature of female for several reasons. First, the male flowers are very short lived, generally they bloom and decay within 2 or 3 days. As flowering is seasonal in most pandans, whole fruit development is a lengthy process; there is much higher probability of finding pistillate trees with probably developed fruits, than there is finding staminate specimen with fresh flower at anthesis. The duration of a staminate inflorescence is usually only one to three days, while the flowering season may

Fig. 12. Summary of contrasting characters of *Pandanus bantamensis*, *P. pseudolais* & *P. scabrifolius* in Java.

Character	<i>P. bantamensis</i>	<i>P. pseudolais</i>	<i>P. scabrifolius</i>
Leaf base colour	Reddish brown 	Reddish brown 	Yellowish white 
Peduncle shape	Bit curved at the end 	Curved at the end 	Straight 
Fruit shape	Cylindric-suboblong 	Oblong-ellipsoid 	Subglobose 
Style shape	Bifurcate nearly half way 	Hornlike 	Bifurcate almost at the end 

only be a week or two. In contrast, fruit development may take several months. Second, the staminate material is poorly represented in herbarium and in collection, so correlated staminate and pistillate materials proven by the collection to represent the sexes of a single species are rare. Thirdly, isolated staminate collection in themselves are useful, but may be unidentifiable. However, since the whole taxonomic system is based upon characters of the pistillate plants, such species are often fascinating but frustrating until the female are discovered. The fruits provide preservable characters, readily observable and greater number of useful features for identification.

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